Radiotherapy and Oncology 148 (2020) 274–278

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

COVID-19 Rapid Communication

Evolution of clinical radiotherapy physics practice under COVID-19 constraints ☆

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ARTICLE INFO

Article history:
Received 29 March 2020
Received in revised form 9 May 2020
Accepted 17 May 2020
Available online 29 May 2020

Keywords:
COVID-19
Pandemic
Contingency plan
Coronavirus
Medical physic
Clinical physic

ABSTRACT

As the COVID-19 spread continues to challenge the societal and professional norms, radiotherapy around the globe is pushed into an unprecedented transformation. We will discuss how clinical physics has transformed to ascertain safety and quality standards across four facilities around the world through diversity of action, innovation, and scientific flexibility.

The COVID-19 pandemic, caused by the SARS-CoV-2 virus, has led to over 6.5 million confirmed infections and 380,000 deaths globally [1]. As of now, any specific treatment or vaccine is lagging behind the rapid spread of this contagious illness. The aerosol and fomite transmission of the agent is likely and the experimental studies have demonstrated that the SARS-CoV-2 can survive several hours in air (and up to several days on certain surfaces) [2]; hence the natural course of action against the disease is to avoid exposure from the respiratory secretions of an infected individual [3]. In order to slow down spread of the disease, WHO and various national health agencies recommend physical distancing of 2 m between individuals which is being implemented as "social-distancing" in various parts of the world. This very benign advice has caused mayhem in all walks of modern life. From Asia to the Americas, almost everywhere, states, and jurisdictions have imposed restrictions on non-essential contact by issuing stay-at-home, or lock-down orders. In hospitals, including radiation oncology facilities, prevention and control measures are in place to ensure safety of the cancer patients, health professionals and caregivers, and to manage treatment of suspected or COVID-19 positive cancer patients. Clinical workflow and contingency measures from several radiation therapy (RT) departments are now part of the emerging literature [4–18]. Several individuals and organizations, such as ASTRO and ESTRO, have published opinions, recommendations and guidelines on RT management of cancer patients, such as for head and neck [19,20], lung [21], breast [22], gastrointestinal [23], gynecological [24], rectum [25], prostate [26], and emergency palliative care [27].

Medical physicists across the world provide supporting roles in RT including administration, direct clinical services, equipment performance evaluation, quality assurance, safety, informatics, education and training, research, and service development [28,29]. In order to execute these tasks safely and efficiently, they have to operate in teams, supervise staff, provide consultation and in some activities face-to-face patient interactions. Although the philosophy behind clinical physics operations is similar, various tasks can be accomplished in different order or under different constraints arising from organizational culture and operational environment. Under various constraints of social distancing, one important question commonly asked is: "how much quality assurance (QA) is enough?" Since the COVID-19 outbreak, there has been a sudden transformation of clinical physics tasks with no

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https://doi.org/10.1016/j.radonc.2020.05.034
0167-8140/

historical precedent, it is therefore prudent to review and document how the practice patterns have changed in different parts of the world [18]. The majority of emerging literature lacks details of how various clinical physics workflow and operations have adapted to the new realities. Therefore, in this work, we will provide a snapshot of common radiotherapy physics workflow across a geographical sample of clinics in North America and Europe with the aim that it will provide supporting data to develop some consensus through diversity of approaches. These clinics operate under various fiscal models, human resources, societal norms, and other healthcare constraints.

Methods

Four variable sized, geographically distributed, cancer clinics A (St. Louis, MO, USA), B (Victoria, BC, Canada), C (Exeter, Devon, UK) and D (Campobasso, Italy) were included in this study. Except for A, all other clinics operate under public healthcare model. Clinic A represent a large academic institution employing 37 full time equivalent (FTE) physicists, with external beam radiation treatments, (EBRT) on 13 Truebeam™ (Varian Medical Systems, Palo Alto, CA) linacs integrated with an Eclipse® and Aria® 15.6 hosted in a cloud network. The clinic also performs MRI-guided radiotherapy (MRgRT) adaptive radiotherapy, proton therapy, several forms of brachytherapy, and various radiopharmaceutical treatments. Clinic B is a tertiary healthcare facility employing nine physicists, offering high dose rate (HDR) gynecology brachytherapy, low dose rate prostate seed implants, radiopharmaceutical treatments and external beam treatments on six Truebeam™ linacs integrated with an Eclipse™ and an Aria® 15.6 platform hosted provincially. Clinic C is a National Health Service (NHS) cancer care facility having nine physicists, offering HDR prostate and gynecology brachytherapy, and EBRT on three Varian linacs integrated into an Aria® 15.6 platform hosted locally. Clinic D is a public cancer care facility with three physicists, offering EBRT on two Versa HD Elekta™ linacs (Elekta Oncology Systems, Crawley, UK) integrated into a Mosaiq® 2.64 platform hosted locally.

The main goal of all four facilities in responding to the current situation was to sustain safe and efficient operability of radiotherapy under the constraints of social distancing and local guidelines. All radiotherapy treatments involve general work flow as follows (Fig. 1).

A summary of clinical physics practice patterns for the four radiotherapy facilities both prior to and during the outbreak is provided in Table 1, where tasks are allocated to those able to be carried out remotely or those needing the physical presence in the clinic of a physicist. The study was restricted to the most common tasks performed by at least three of the participating institutions, other specialized tasks for total body irradiation (TBI), MRgRT, proton therapy etc., were not included in the comparison.

General response to disruption

In order to avoid possible spread of the contagion, the physics staffing was split into two teams: on-site and remote; their roles would be exchanged on a weekly basis or between early and late shift. Each team member was selected based on their ability to perform a variety of procedures. The site team practiced physical distancing, and used appropriate personnel protective equipment (PPE) when called to a procedure room.

In response to the pandemic, the medical physics tasks were prioritized into essential tasks and non-urgent tasks that can tolerate delays and postponement (e.g., annual QA). Patient-specific QA, equipment QA, and commissioning of equipment and safety checks following relevant maintenance interventions were prioritized.

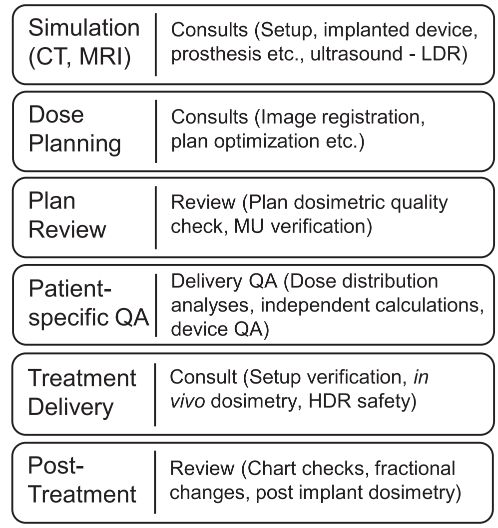

Fig. 1. General radiotherapy process and clinical physics roles. The process elements are adaptable for stereotactic body radiotherapy (SBRT), high dose rate (HDR), low dose rate (LDR) brachytherapy, stereotactic radiosurgery, (SRS) and 3D conformal radiotherapy (3D-CRT).

The QA activities were moved to after-hours or weekends where possible such as therapy equipment calibration, machine QA and testing. Followed by the QA measurements, appropriate disinfecting protocols were adopted to avoid possible contamination of the treatment equipment. In case of clinic D, patient-specific QAs were performed early in the morning, prior to the start of treatments.

The radiotherapy planning and management systems were set up for remote working; in two institutions the information technology (IT) infrastructure was cloud-based, while in others, planning desktops and other computers were accessed through a remote desktop application.

All communication between both teams and other RT staff were accomplished through voice/video conferencing software through Microsoft Teams (Microsoft, Redmond, WA) or Zoom (Zoom Video Communications Inc., San Jose, CA). In all cases, it was ensured that the software and hardware were compliant to country-specific regulations regarding patient privacy and data security by checking with the providers.

Using either cloud-hosted treatment planning and management system or remote access software, all four clinics could perform the bulk of the plan quality checks, image registration, 3D-CRT, IMRT and VMAT plan reviews, special techniques SRS, SBRT, etc. and even HDR planning and reviews without compromising quality. At each facility, interactions with other team members such as radiotherapy technologists (RTTs), treatment planning dosimetrists, and radiation oncologists, was achieved via virtual meetings and shared screens.

Some tasks required on-site attendance by the physicist such as patient setup and IGRT checks for SRS, SBRT, etc. on the first day of treatment. All institutions required physical presence of a specialized physicist during the HDR brachytherapy delivery due to state regulations.

Initially, following the guidelines for RT, a surge in number of hypofractionated treatments across all four facilities happened, which increased the clinical workload for about one week due to re-planning of some patients undergoing treatment. However, this may be mitigated by the smaller overall number of fractions needed over a period of time.

Contingency plans were developed for possible radiotherapy of COVID-19 infected cancer patients if required. This involved either

Table 1
Summary of practice patterns for common radiotherapy tasks performed by the clinical physicists prior to and during the COVID-19 outbreak. * represents physics consults – only if requested; ** shows physical presence requirement during the RT delivery by regulatory agencies.

Technique/	3D Conformal RT	Modulated therapy (IMRT/VMAT)	Hypo-fractionated RT/ SBRT	Single fraction Stereotactic radiosurgery (SRS)	Brachytherapy (HDR and LDR seeds)
Prior to disruption	Plan review; secondary MU check	4DCT simulation*, initial plan review, final plan review; MU calc; delivery QA	4D CT & motion management*, fusion review, plan review, first fraction patient setup, plan delivery QA	CT & MR, motion management & simulation, planning, plan review, delivery QA & collision check; patient setup and treatment delivery**	HDR: plan review, QA, and delivery** LDR: ultrasound simulation, planning, QA, delivery, and post implant
During disruption	All remote	All remotely except, patient-specific delivery QA	All remotely except first fraction patient setup and patient specific delivery QA	All remotely except for simulation and delivery**	HDR: All remote except the delivery** LDR: ultrasound simulation, seeds QA, delivery in person; rest are done remotely

For IMRT and VMAT QA, clinic B uses an in-house Monte Carlo-based independent dose calculation software or occasional portal dosimetry measurements. Clinic B continued to perform on-site initial modulated plan consultation and for single fraction treatments. Clinic C does not perform single fraction SRS treatments. Clinic D physics staff also does treatment planning for modulated and hypofractionated treatments. Single fraction treatments are planned by physicists at D; Gammaknife® SRS treatments at clinic A are planned by a physicist. Clinic D does not perform any of the brachytherapy procedures listed above.

dedicating a linac for the treatment, or treating the patient during the last time slot of the day. This is similar to existing protocols already in place for radiotherapy of cancer patients with infectious conditions. Following the treatment, the room would be thoroughly disinfected, and not used for the next 12 hours to ensure no virus survived in the treatment space. In general, all new patients with confirmed COVID-19 would have radiotherapy delayed for several weeks. On-treatment patients identified with COVID-19 + would be carefully evaluated according to their clinical situation. If treatment cannot be stopped, patients must be treated following the contingency plan described above. To date, none of the participants have treated a known COVID-19 + patient with radiotherapy.

Institution specific details

Remote physics operations at institution A were initiated on March 16. This involved all administration and treatment planning dosimetrists to operate fully remotely, whereas physicists were split into on-site and remote teams. Telecommuting has continued unabated since then. The average fractions treated per day dropped by about 20% since COVID-19 impacted operations began. The physicians changed some plans to hypofractionated regimens, which lead to surge in plan complexity and workload for about one week. Due to a sufficient number of staff, the workload was manageable. One week into the outbreak, two linacs were shut down to have back-up therapists in order to overcome any shortage of staff due to disease or other issues and also to use the rooms for possible COVID19 + radiotherapy.

At institution B, one major advantage was using an in-house Monte Carlo-based independent dose calculation for IMRT/VMAT patient specific QA (if measurement is required it was performed using EPID dosimetry afterhours) which further helped with telecommuting.

At institution C, telecommuting operations started the week of the March 23, which coincided with the beginning of general lockdown measures in the UK, and then was expanded to administrative and all treatment planning staff. Breast and prostate treatments were converted to hypofractionation with a general trend to hypofractionate other sites (sarcomas, rectum, etc.) where possible. New starts for prostates were initially put on hold, later they were resumed with various hypofractionated regimens (36 Gy in 5 fx or 60 Gy in 20 fx). All prostate HDR and radioiodines for thyroids were delayed indefinitely; only HDR treatments were allowed for the gynecological sites. The reduction from 15 fractions (for 40 Gy prescription) to 5 fractions (36 Gy prescription) for most breast treatments was the major contributor to the overall reduction of the total patient workload.

The modified operations at institution D started on March 2, 2020, and the radiotherapy schedules rapidly moved towards hypofractionation. Since Clinic D was the only regional hospital providing radiotherapy, one of the major objectives was to maintain full access to radiation treatment even under emergency. The number of daily treatment slots were not decreased. Instead, by rearranging the work shifts and extending the treatment day by extra three hours, spatial and temporal distancing between patients and staff was ascertained. Since Italy was the first European country to witness a widespread outbreak of the coronavirus, the government decreed increased restrictions within lockdown areas/"red zones", which were later extended to the whole nation on March 8, 2020. The Italian Association of Medical Physics (AIFM) [30], following the suggestions of the European Federation of Medical Physics Organizations (EFOMP) [31] issued directives for the medical physics units operating in hospitals, with the aim to keep treatment and diagnostic procedures as safe as possible. Being a small physics group, to ensure social distancing, all on-site physics personnel operated in separated areas and rooms, while one physicist remotely worked from home (WFH) using web-conferencing and on-line meeting tools.

General discussion and challenges

In the absence of professional guidelines on clinical physics tasks during COVID-19, the goal of this short study was to understand adaptation of medical physics operations in various environments, learn from mutual experience and help develop some consensus on elasticity of physics tasks. The healthcare system in the United States is mostly privately owned and operated, unlike public or universal healthcare systems of Canada, United Kingdom and Italy. This can lead to different approaches from higher management when it comes to crisis management. The major objective of moving to a partially remote model was to provide unhindered safe clinical support for radiotherapy of cancer patients, should some of the physics staff become unavailable from infection or other need to isolate. It may be noted that similar solutions were adopted in reference [18], which presented specific discussion of medical physics issues for COVID-19 operation of radiotherapy services in an Australasian context.

One of the challenges at institution A was rationing and limited supply of PPE for the physics staff. After about one month of remote operations, WFH has been stressful for the physics team due to lack of interpersonal communication, face-to-face interactions, bonding and inclusion, though modern communication channels have provided some mitigation [32].

Due to restrictions on international travel, border closures, and supply-chain issues, mobility of goods and RT supplies has become uncertain. Radioactive ^{125}I seeds treatments can suffer greatly due to these disruptions resulting in potential cancelation of LDR procedures.

There are some positive spinoffs of the COVID-19 work challenge. The institutional IT departments had to prioritize the implementation of WFH schemes, resistance to paperless initiatives dropped, hypofractionated approaches were implemented for breast and prostate radiotherapy as well as other sites with concurrent gains in time-efficiencies and possibly with equivalent or better outcomes. During the COVID-19 constrained situation a sense of closer working partnership between physicians, RTTs, other technical staff, administrative support and medical physicists has been developing. However, the significant perturbations that the COVID-19 response has caused in terms of delaying radiotherapy, and scaling down of operations (~25%) will create a backlog of patients that will challenge the effective and timely provision of radiotherapy in the very near future. It is critical to prepare for this reckoning, one can hope that the gains of workforce flexibility, telecommuting schemes and hypofractionation-derived efficiencies can counterbalance an impending increased demand for radiotherapy in post COVID-19 era. In addition, any postponed equipment servicing or preventative maintenance will also have to be rescheduled.

Another major challenge especially with smaller operations like clinic D in the current study, was the smaller number of staff which made it difficult to operate as two completely independent groups. The staff reorganization was done to avoid any aggregation of personnel while guaranteeing the availability of staff and vital resources for the continuity of care.

Though prioritizing of physics tasks in this work was done heuristically and in order to react speedily to the developing crisis, it may be more appropriate to deploy a systematic reliability engineering approach such as an institution-specific failure modes and effect analysis (FMEA) [33] to perform risk analysis for prioritizing QA tasks. There is also an imminent need for a professional medical physics task force to develop consensus on clinical physics tasks under a pandemic or major catastrophe. Only a consensus can address the amount of QA, preferred order of operations and other relevant questions.

While we acknowledge that providing recommendations during the spread of pandemic is challenging due to lack of data points and the changing nature of the spread, sharing the commonalities and contrasts of our experiences across these four cancer clinics operating under different healthcare norms, along with those from [18], could lead to consensus among the physics community.

Conflicts of interest

The authors have no conflict of interest to disclose.

Acknowledgements

All authors would like to acknowledge useful discussions with other colleagues at their respective institutions. The authors are grateful to the referee for his/her valuable comments which improved the quality of the manuscript.

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